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THE PROBLEM OF HYGIENIC STANDARDIZATION OF AIR CONCENTRATION OF MICROORGANISMS IN OFFICE PREMISES

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Introduction. Today there is an urgent need to create regulations governing the level of microorganisms in the air of office premises. This problem in Ukraine did not attract as much attention as it did now, during the COVID-19 pandemic. In other countries, on the other hand, it has not only been the subject of researches for the past 20 years, but has also introduced certain sanitary rules that employers must follow. In particular, according to research conducted in the United States, indoor air pollution is one of the five most dangerous factors for human health. The most important component that determines the safety and suitability of air is its microbiome, which may contain both pathogenic microorganisms and microorganisms that are not dangerous, but can cause adverse reactions: allergies, immune system stress and more.

The purpose of the study is to analyze the literature and regulatory framework in Ukraine and other developed countries regarding the hygienic regulation of microbiological condition of office air.

Materials and methods of research. Analytical review of scientific publications was carried out using scientometric databases, sanitary legislation of developed countries, periodicals and publications.

Results. In the USA, the EU, Japan, Brazil and many other developed countries of the world there are hygienic standards that regulate the permissible limits of the number of microorganisms in the air of office premises. It should be noted that these regulations have significant differences in methodological approaches to risk assessment and criteria. Basically, from 250 to 1000 colony-forming units/m^3 are allowed for bacterial microflora and fungi according to the standards of different countries and organizations. Literature data show a significant correlation ($r = 0.35–0.40$) between the concentration of microorganisms (bacteria and fungi) in indoor air and microclimate parameters, which may be the basis for improving prevention measures. In Ukraine today, the regulatory framework for the number of microorganisms in the air applies only to premises in health care facilities or premises in the production of pharmaceutical products or food businesses. At the same time, regulations on administrative or office space that would provide safe limits for the presence of microorganisms in their air – have not been developed and implemented in health care practice.

Conclusions. There is a significant need to develop sanitary and anti-epidemic rules for work in office premises in Ukraine, which, in particular, regulates the number of microorganisms (bacteria and fungi) in the air. To address this issue, the scientific and regulatory experience of the EU, the US and other developed countries in regulating the permissible concentration of microorganisms in office air can be very useful. Also, it is very important to consider not only the quantitative but also the qualitative composition of the microbial environment that can affect the human body. When developing preventive measures, it is quite appropriate to determine the impact of microclimatic conditions and other physical factors on the air microbioma.

Key words: office premises, bacteria, fungi, viruses, air

Introduction

A history of «clean premises» concept begins at the second half of the nineteenth century. Well-known surgeon Joseph Lister put forward a theory: getting rid of bacteria in hospitals, especially operating rooms, should prevent infections. When he started implementing this, the result was a significant reduction in infectious complications after surgery. His concept of reducing the risk of bacterial infection during surgery was based on the active use of disinfectants on surgical instruments, materials, surgeon's hands and the environment [1].

This was a significant step forward, which reduced the risks for patients. However, one important element of modern technology to ensure cleanliness was missing – ventilation with filtration of the air flow entering the room. In general, by the middle of the

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twentieth century. this issue could not be resolved. Such ventilation was only as a system of additional comfort, not an element of air purification.

It should be noted that air purification in special purpose premises is only one side of the coin. The main effort to create a clean premises in medicine is quite understandable. After all, it is in medical institutions that the cleanliness of the premises, and especially its microbiological cleanliness, is a critical factor that not only affects the quality of treatment, but can be crucial for the recovery of patients. Requirements for drug production were developed separately. And here the cleanliness of the room also plays a key role. The second stage of development was the introduction of cleanliness in the premises, which were directly related to the production and preparation of food. At the same time, when we talk about office space, the rules that applied to it were completely different. These are light, temperature, humidity, noise level, etc. The microbiological component was not taken into account at all.

The purpose of the study is to analyze the literature and regulatory framework in Ukraine and other developed countries regarding the hygienic regulation of microbiological condition of office air.

Materials and methods of research

Analytical review of scientific publications was carried out using scientometric databases, sanitary legislation of developed countries, periodicals and publications.

Results and their discussion

Today, a huge number of employees spend their working time in the office and the cleanliness of its air is also extremely important. This affects not only the ability to work, but also the health of the employee in general.

According to research conducted over the past 20 years by the United States Environmental Protection Agency, indoor air is often more polluted than outdoor air, and indoor air pollution is among the five most dangerous risks to public health [2, 3].

Today in the scientific and popular science literature can often be found the term «sick building syndrome» (SBS), which is used to describe a situation where residents of certain houses and premises have a set of certain diseases and symptoms, but no specific diseases. In 1984, the World Health Organization (WHO) reported that «sick building syndrome» occurs in 30 % of new and renovated buildings in the world. SBS is associated with a group of pathological conditions of the mucous membranes, skin and general symptoms that are associated with work in specific buildings [4]. One of the main causes of SBS can be contamination by fungal microflora of the premises where people are. The parameters of the microclimate, especially humidity and temperature which affect the state of the microflora of the room are important, also [5]. At the same time, houses built of cheap building materials to save money and save energy may have a SBS more often than others.

A dose of microorganisms is a very important factor in an inhaled air. The dose is the number of microorganisms that actually enter the body and reach the target tissue. Differences in respiration in each individual mean that the same exposure may not result in an identical dose. Levels of personal individual susceptibility vary widely and this explains why the inhalation dose was not set as a characteristic of the real risk of workers from exposure to office air microbiome during their work [6].

In the air of the office there is the presence of so-called «bioaerosol». It accounts for up to 34 % of the total aerosol in the air [7]. Liquid droplets and solid particles form a colloidal suspension, which is called a bioaerosol. Particles in the air may contain bacterial cells, fungi, viruses, fragments and parts of these microorganisms, their spores, products of their activity and metabolism (in particular, mycotoxins; endotoxins), plant pollen and plant tissue fragments. All this makes bioaerosols a serious risk to the health of workers, mainly because bacteria, viruses and fungi in the air can cause infectious diseases, as well as allergies and toxic effects. On human skin, in the mouth and nose, there are a large number of microorganisms that can enter the airspace of the office and accumulate there. Microorganisms from the soil or from plants can also be introduced by office workers or get outside with dust [8–10]. Humans are the main source of certain bacteria and viruses. Even more, they are sometimes the source of certain species of fungi for which humans do not seem to be a typical carrier. However, human activity plays a major role, for example, the transfer of solid dust particles on clothing, or the perturbation of a suspension of dust that has settled, and all this may contain microorganisms of various kinds.

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Detection of viruses in the air lags far behind the ability to identify bacteria or fungi. Only due to the development of polymerase chain reaction (PCR), this task has become somewhat easier. In addition, data from one study, which was aimed to detect flue A virus, showed interesting results [11]. During the 2009–2010 epidemic season, samples of particles of different sizes are collected in films in three types of examples: a medical center, a kindergarten, and on board three aircraft. A total of 16 air samples were collected and 8 of them (50 %) contained influenza A gene material with a concentration of 5,800 to 37,000 genomes per m^3, as well as part of the detected virus used with small particles < 2.5 μm, which can suspended for a long time in the air and when inhaled to penetrate deeply into the respiratory tract (Figure 1).

Studies of the activity of the working population show that during 8 hours working day, the only effective technical solution that can improve air quality and provide workers with proper working conditions is the air conditioning system [12, 13]. The outside air coming through this system must be free of contaminants and have the appropriate temperature and humidity. Air conditioning systems can get rid of up to 80 % of external pollution, but they can also create favorable conditions for the development of different microorganisms. Improper and insufficient maintenance of air conditioning systems can often lead to indoor air pollution [14, 15]. In this case, the main sources of air pollution in the office can be several factors. First of all:

- *air coming from outside*, which is already polluted with dust and other particles that have not passed the air conditioning system;
- *man* as an inexhaustible source of various microorganisms living on his skin and mucous membranes. When sneezing, coughing or even talking, a person produces an aerosol that spreads them throughout the air. The second way in which a person carries microorganisms indoors is the resuspension of settled particles when walking or any other movement inside the room [16];
- *molds and high humidity* which are one of the important sources of pollution in buildings. Spengler et al. (1994) reported that half of the surveyed households in 24 cities in the United States and Canada had problems related to humidity (water damage, basement water, and/or mold) [17].

The release of spores of Aspergillus versicolor, Cladosporium cladosporioides and Penicillium melinii from ceiling tiles and their distribution depending on the air velocity near the surface and the vibration of the contaminated material have been described [18]. In another study, the release of (1 → 3) -β-D-glucan from the surface of the affected mold tiles of the ceiling and drywall was investigated [19]. In many buildings, moisture or condensate penetrates wall cavities or other hidden areas associated with the main airspace. This contributes to the fact that mold spores effectively enter the main room [20], as most fungal spores have a diameter of less than 10 μm, and cracks and gaps, as well as internal wall cavities, even at minimum sizes, usually exceed 1 mm. This is fully confirmed by the conclusion about the penetration of particles of different sizes (Figure 2) [21].

It is worth mentioning the non-infectious effect of microbial particles that enter the body during respiration. Even if these microorganisms do not cause disease, they can cause an inadequate immune response, as a result of which inflammation develops and a pathological process can begin [22].

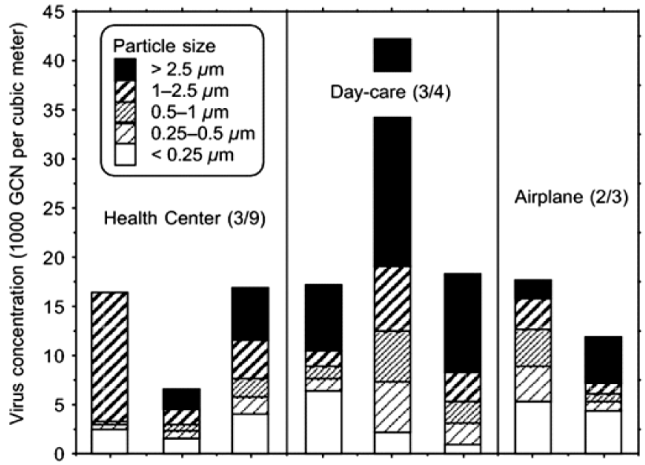

Figure 1. Concentrations of detected genetic material of influenza A virus [11]

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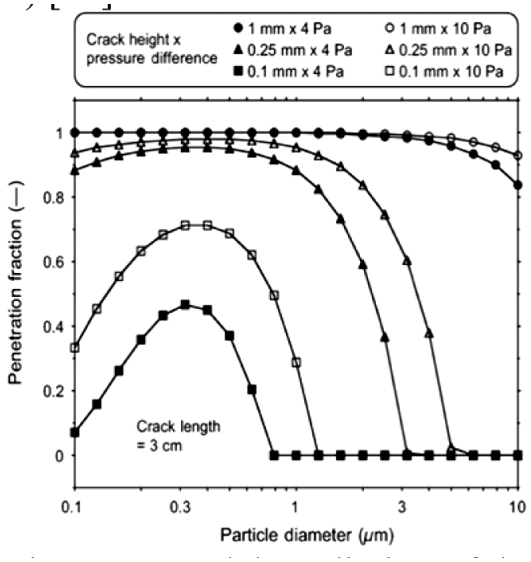

Figure 2. Model prediction of the dependence of the possibility of penetration of particles on the size through cracks inside the building [21]

It should be noted that the standards of the Soviet period, GOST (in particular GOST 12.1.008-76) and sanitary and anti-epidemic rules applied only to the premises of health care facilities, food and processing industry, research institutions and pharmaceutical industries. Standards that would regulate the number of microorganisms in the air of office premises in Ukraine have not yet been implemented. At the same time, in the EU, for example, in Italy, several pieces of legislation, in particular Decree 81/2008, stipulate that employers are responsible for assessing the risks of biological origin arising from workplace activities; in addition, they must take appropriate measures to keep the air in the workplace clean [23, 24].

Today we can give a few more examples of normalization of the amount of microflora in the room air. The following gradation of the level of bacteriological air pollution has been introduced in the EU: 0 colonies forming units (CFU) – undetectable; 1 – 499 CFU/m^3 – low level; 500–999 CFU/m^3 – average level; > 1000 CFU/m^3 – high level; 2000 CFU/m^3 – a very high level, the value of 10 000 CFU/m^3 in air is considered a dangerous level for premises [25].

In 2001, the American Industrial Hygiene Association (AIHA) published a proposal for a guideline in which 1000 CFU/m^3 in indoor air is the upper limit of the permissible concentration of indoor microflora. They proposed to set permissible levels at > 500 CFU/m^3 for residential premises and > 250 CFU/m^3 for commercial buildings [26, 27].

According to the current Swedish requirements, the norm for the room is to detect no more than 500 CFU of bacteria and 300 CFU of fungi in 1 m^3 [28].

In Brazil, the regulation stipulates that the upper limit of the total number of microorganisms in the air (especially, fungi) should not exceed 750 CFU/m^3 [29, 30].

In Hong Kong, the number of microorganisms in indoor air must be less than 1000 CFU/m^3. The level less than 500 CFU/m^3 is considered to be excellent [31, 32].

In Taiwan, the level of microorganisms in the airspace of rooms should not exceed 500 CFU/m^3 for bacteria and 1000 CFU/m^3 for fungi [33, 34].

Mathematical analysis shows a significant correlation (r = 0.35–0.40) between the number of microorganisms (bacteria and fungi) in the air and the parameters of the microclimate, especially relative humidity, which is the basis for further development of prevention measures.

In Singapore, it is assumed that indoor air can contain up to 500 CFU/m^3 of microorganisms [36].

There are some methodological approaches to the assessment of microbial environment in residential areas, taking into account its composition and climatic conditions. Thus, according to the recommendations of the Dutch Association of Medical Workers, the potential danger to human health poses a mixture of microorganisms of more than 10,000 CFU/m^3 or more than 500 CFU/m^3 for potentially dangerous species. The Ministry of Health of Finland for the maximum acceptable concentrations of microorganisms in residential premises: < 500 CFU/m^3 in winter and < 2500 CFU/m^3 in summer [37].

In Germany according to the standard SBM-2003: in the air < 200 CFU/m^3 – «no anomaly», 200–500 CFU/m^3 – «slight anomaly», 500–1000 CFU/m^3 – «strong anomaly», > 1000/ CFU/m^3 – «extreme anomaly» (values refer to indoor air when outdoor reference levels are relatively low, below 500/m^3); on surfaces: < 20 CFU/dm^2 – n o, 20–50 CFU/dm^2 – «slight», 50–100 CFU/dm^2 – «strong», > 100 CFU/dm^2 – «extreme anomaly» (values refer to surfaces that are subject to common and regular cleaning practices) [37].

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Thus, today in the world there is no a uniform standard for assessing the microflora in the air of office premices. The above data indicate a significant difference in methodological approaches for assessing the potential risks of microflora in the air according to the standards of different countries, which should be taken into account when developing appropriate sanitary standards for office space in Ukraine.

Conclusions

1. The purity of air, in particular, its microbial composition (the presence of certain microorganisms: bacteria, viruses or fungi) is the subject of sanitary legislation in developed countries. Sanitary standards for the quantity and quality of microorganisms in premises are regulated by legislation of both a particular country's and interstate formations, such as the European Union. At the same time, these norms are quite strict and, most importantly, for their violation there are penalties that actively encourage compliance with these rules. It should be noted that these regulations have significant differences in methodological approaches to risk assessment and criteria. Basically, from 250 to 1000 colony-forming units/m^3 are allowed for bacterial microflora and fungi according to the standards of different countries and organizations.
2. It is very important to consider not only the quantitative but also the qualitative composition of the microbial environment that can affect the human body. After all, financial losses due to sick leaves, the emergence of chronic and autoimmune diseases are very significant.
3. An integrated approach should be considered when developing air purification and disinfection of air and work surfaces in premises. In particular, the impact on the microclimate of the premises and the microbe of other physical factors: lighting, irradiation. After all, their correct combination not only cleans the airspace, but also creates the conditions for preventing the development of unwanted microorganisms. Literature data show a significant correlation ($r = 0.35–0.40$) between the concentration of microorganisms (bacteria and fungi) in indoor air and microclimate parameters, which may be the basis for improving prevention measures.

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ДО ПИТАННЯ ГІГІЄНІЧНОГО НОРМУВАННЯ КІЛЬКОСТІ МІКРООРГАНІЗМІВ У ПОВІТРІ ОФІСНОГО ПРИМІЩЕННЯ

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Вступ. Сьогодні існує нагальна необхідність створення нормативних актів, що регламентують рівень мікроорганізмів у повітрі офісних приміщень. Раніше в Україні це питання не привертало таку увагу, як це сталось нині, у період пандемії COVID-19. Однак в інших країнах це є не лише об'єктом досліджень останніх 20 років, але й введено певні санітарні правила, яких роботодавець має дотримуватись. Зокрема, згідно з проведеними у Сполучених Штатах Америки (США) дослідженнями, забруднене повітря в приміщенні входить до 5 найнебезпечніших факторів для здоров'я людини. Найважливішою складовою, що визначає безпечність і придатність повітря, є його мікробіом, який може містити як патогенні мікроорганізми, так і мікроорганізми, що не будучи небезпечними можуть викликати негативні реакції організму: алергії, навантаження імунної системи тощо.

Мета дослідження – провести аналіз даних літератури та нормативно-правової бази в Україні й інших країнах щодо гігієнічної регламентації мікробіологічного стану повітря офісних приміщень.

Матеріали та методи дослідження. Аналітичний огляд наукових публікацій проведено з використанням наукометричних баз даних, санітарного законодавства розвинутих країн, періодичних видань та публікацій.

Результати. У США, Європейському Союзі (ЄС), Японії, Бразилії та багатьох інших розвинутих країнах світу існують гігієнічні стандарти, що регламентують допустимі межі кількості мікроорганізмів у повітрі офісних приміщень. Слід зазначити, що ці нормативні акти мають помітні відмінності в методичних підходах до оцінки та критеріїв ризику. В основному для бактеріальної мікрофлори та грибів за стандартами різних країн й організації допускається 250–1000 колоній утворюючих одиниць/м^3. Дані літератури свідчать про значну кореляцію (r = 0,35–0,40) між концентрацією мікроорганізмів (бактерій і грибів) у повітрі приміщень і параметрами мікроклімату, що може бути основою для вдосконалення заходів профілактики. В Україні сьогодні гігієнічні нормативи щодо кількості мікроорганізмів у повітрі стосуються лише приміщень у закладах охорони здоров'я або приміщень на виробництві фармакологічної продукції чи харчових підприємствах. У той самий час нормативних актів щодо адміністративних чи офісних приміщень, які б давали безпечні межі наявності мікроорганізмів у їхньому повітрі – не розроблено й не впроваджено в практику вітчизняної охорони здоров'я.

Висновки. В Україні існує помітна потреба в розробці санітарно-протиепідемічних правил роботи в офісному приміщенні, що, зокрема, регламентує кількість мікроорганізмів (бактерій і грибків) у повітрі приміщення. Для вирішення цього питання дуже корисним може стати науковий і нормативно-правовий досвід ЄС, США та інших розвинених країн щодо регулювання допустимої концентрації мікроорганізмів у повітрі офісних приміщень. Водночас дуже важливо враховувати не тільки кількісний, а й якісний склад мікробного середовища, здатного впливати на організм людини. При розробці профілактичних заходів достатньо слушним є визначення впливу мікрокліматичних умов й інших фізичних факторів на мікробіом повітря.

Ключові слова: офісні приміщення, бактерії, грибки, віруси, повітря

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К ВОПРОСУ ГИГИЕНИЧЕСКОГО НОРМИРОВАНИЯ КОЛИЧЕСТВА МИКРООРГАНИЗМОВ В ВОЗДУХЕ ОФИСНОГО ПОМЕЩЕНИЯ

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Введение. На сегодняшний день существует настоятельная необходимость создания нормативных актов, регламентирующих уровень микроорганизмов в воздухе офисных помещений. До этого в Украине этот вопрос не привлекал такого внимания, как это произошло сейчас, в период пандемии COVID-19. В других странах это является не только объектом исследований последних 20 лет, но и введены определенные санитарные правила, которые работодатель должен соблюдать. В частности, согласно проведенным в Соединенных Штатах Америки (США) исследованиям загрязненный воздух в помещении входит в 5 наиболее опасных факторов для здоровья человека. Важнейшей составляющей, определяющей безопасность и пригодность воздуха, является его микробиом, который может содержать как патогенные микроорганизмы, так и микроорганизмы, которые не будучи опасными могут вызвать негативные реакции организма: аллергии, нагрузки иммунной системы и т. д.

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Цель исследования – провести анализ данных литературы и нормативно правовой базы в Украине и других странах относительно гигиенической регламентации микробиологического состояния воздуха офисных помещений.
Материалы и методы исследования. Аналитический обзор научных публикаций проведен с использованием наукометрических баз данных, санитарного законодательства развитых стран, периодических изданий и публикаций.
Результаты. В США, Европейском Союзе (ЕС), Японии, Бразилии и многих других развитых странах мира существуют гигиенические стандарты, регламентирующие допустимые пределы количества микроорганизмов в воздухе офисных помещений. Следует отметить, что эти нормативные акты имеют заметные отличия в методических подходах к оценке и критериям риска. В основном для бактериальной микрофлоры и грибов по стандартам разных стран и организации допускается 250–1000 колоний образующих единиц/м^3. Данные литературы свидетельствуют о значительной корреляции (r = 0,35–0,40) между концентрацией микроорганизмов (бактерий и грибов) в воздухе помещений и параметрами микроклимата, что может служить основой для совершенствования мер профилактики. В Украине сегодня гигиенические нормативы относительно количества микроорганизмов в воздухе касаются только помещений в учреждениях здравоохранения или помещений на производстве фармакологической продукции или пищевых предприятиях. В то же время нормативные акты относительно административных или офисных помещений, которые бы давали безопасные пределы наличия микроорганизмов в их воздухе – не разработаны и не внедрены в практику отечественного здравоохранения.
Выводы. В Украине существует заметная потребность в разработке санитарно-противоэпидемических правил работы в офисном помещении, что, в частности, регламентирует количество микроорганизмов (бактерий и грибков) в воздухе помещения. Для решения этого вопроса может стать полезным научный и нормативно-правовой опыт ЕС, США и других развитых стран по регулированию допустимой концентрации микроорганизмов в воздухе офисных помещений. При этом очень важно учитывать не только количественный, но и качественный состав микробной среды, способной влиять на организм человека. При разработке профилактических мероприятий достаточно удобно определить влияние микроклиматических условий и других физических факторов на микробиом воздуха.

Ключевые слова: офисные помещения, бактерии, грибки, вирусы, воздух

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